Marine Protected Areas in the context of climate change: key challenges for coastal social-ecological systems

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Abstract : Climate and ecological emergencies play out acutely in coastal systems with devastating impacts on biodiversity, and the livelihoods of communities and their cultural values. Marine Protected Areas (MPAs) are one of the key management and regulatory tools against biodiversity loss, playing a role in strengthening bio-cultural diversity and sustainability of coastal social-ecological systems. What is unclear though is the effectiveness of static protections under climate change as species move. Next to ecological uncertainty, regulatory uncertainty may play a role in weakening marine conservation. We asked whether MPAs are ecologically effective now and can sustain or improve to be so in the future, while facing key climate and regulatory uncertainties. MPAs can support the protection of cultural values and have an impact on activities of sea-users and the sustainability of social-ecological systems. As such, questions surrounding their legitimacy under a changing climate and increased uncertainty are pertinent. We argue that MPA governance must be cognisant of the interdependency between natural and human systems and their joint reaction to climate change impacts based on an integrated, co-developed, and interdisciplinary approach. Focusing on the UK as a case study, we highlight some of the challenges to achieve effective, adaptive and legitimate governance of MPAs.

1. *Introduction*

Coasts are at the interface of atmosphere-land-sea interactions (1), exposed to cascading and compounding pressures from climate change (2), and changes to terrestrial and oceanic environments. Coastal ecosystems harbour vast biodiversity, not only in the iconic coral reefs but from the poles to the tropics in kelp forests, maerl and oyster beds and seagrass meadows (3). In 2020, almost 11% of the global population live in coastal areas, from small scale settlements to large mega cities, and these numbers are projected to increase (4). Therefore, our coasts are intersections of the needs of ecosystems and people (5).

Human societies depend on marine ecosystems, for food, climate regulations, coastal protection, and culturally (6). The oxygen for every second breath humans take is provided by photosynthesis of marine algae, although the economic value of this fundamental ecosystem service is often overlooked (7). Less tangibly, blue spaces are important for mental health for example reducing anxiety and depression (8). Thus, marine environments are social-ecological systems (SES) where social and ecological variables interact in complex and multiple ways (9).

The concept of SES helps to overcome false dichotomies between nature and society as well as between ecocentrism and anthropocentrism in conservation law by emphasising the mutually constitutive nature between social and ecological factors. These social-ecological interactions, for example, among resources, users, and governance systems, combined with feedbacks amongst these subsystems, result in complex responses to changes to any parts of the SES. Moreover, these complex interactions, feedbacks and emergent outcomes are exacerbated under environmental and climate change (10), which necessitates new thinking around existing management tools and approaches.

Environmental and climate change are projected to results in increasing risks over the next decades. In interconnected terrestrial-coastal-social systems, environmental dynamics are heavily driven by local factors, e.g. riverine discharge and sediment influenced by land use changes, coastline morphology and infrastructure placement, or resource generation and use, all of which are interacting with global stressors (11). People living by and researching marine and coastal environments have long documented the fact that our coasts are not static environments (12). 71% of the surface of our planet is covered by oceans which have warmed, acidified and lost oxygen over the last century in response to climate change (5) and are impacted by increasing uses and resource extraction (13). This warming has led to the redistribution of species in the ocean with species moving towards to poles (14, 15). Some of these processes impact individual taxa, some habitat forming species which generate biodiversity hotspots (3). Changing species interactions have caused altered

ecosystem structure for example through grazing on coral reefs, kelp forests and seagrass meadows (5). The shifts in spatial distribution of fish, combined with overfishing, is challenging effective fisheries management (16). Functioning ecosystems are essential to meet the UN Sustainable Goals (17), and support human wellbeing (18).

Given the projected changes and demands, marine SES pose unique governance challenges which are exacerbated in coastal zones due to the competition for space between nature and people. Livelihoods e.g. for extraction of resources, tourism, and coastal protection depend on healthy ecosystems (19). A loss of marine and coastal ecosystems, biodiversity, and the ecosystem goods, functions, and services they provide is projected by the middle of this century, impacting these coastal livelihoods (3). Warming lead to coastal inundations due to sea level rise (5). Ecosystem based Adaptation (EbA) and Nature based Solutions (NbS) provide effective coastal protection while also contributing to carbon sequestration (20, 21). Coastal defences are being upgraded and extended to protect assets, altering the habitats they harbour; those these actions might not be enough if sea level rise accelerates as projected (22). At the same time, aquatic food is increasingly considered as a solution to reducing global hunger (23) and renewable infrastructure placed in coastal settings an approach to generate energy and decarbonise our societies (24). Climate change threats are exacerbated by marine pollution, unsustainable use of marine resources and competing spatial claims and conflicts among a varied set of marine resource users (19).

2. MPA for sustainable management of coastal social-ecological systems

Marine Protected Areas (MPAs) are key tools for the sustainable management of coastal and marine SES. They are not the only spatial tools for the governance of marine SESs, with marine spatial planning gaining importance as a means to resolve conflicts between different sea users and pushing for ecosystem-based management (25). Nonetheless, MPAs remain vital management tools to lessen the risks of climate-change hazards and other anthropogenic pressures to coastal ecosystems by aiming to ensure conservation, restoration and sustainable exploitation of resources in our coastal areas, thereby addressing the UN Sustainable Development Goals (esp. Goal 14 and target 14.5) (26).

While MPAs cannot reduce the global impacts resulting risks from climate change (27), they promote genetic diversity, increase population size and ecosystem integrity which are increasing resilience to climate stressors (28). Protected areas are key elements of adaptation but need to be planned and managed to consider shifting species distributions and changes in biological communities and ecosystem structure. Habitat diversification in

protected areas, networks of protected areas and zoning around these can increase the effectiveness of protected areas is supported by national and international projected policies.

Regulators have powers to impose restrictions on activities within MPAs to protect living, non-living, cultural and/or historic resources with the aim of increasing species biomass and population size, enhancing biodiversity and ecosystem structural complexity, and creating or maintaining of refugia habitats (29). Analysis shows that MPAs reduce damage from overfishing and habitat distribution while conserving diversity, though the benefits are highly contingent on effective implementation and management (30). The level of protection ranges from highly protected marine areas to regions in which sustainable use of marine resources is allowed to a large extent (31) with currently (January 2022) 7.9% of the ocean covered by MPAs (32). However, only 2.8% of the ocean is highly protected by designation such as no take areas by the Marine Conservation Institute (33) while many others allow extractive activities (34).

MPAs can have many positive social and economic benefits, including increasing tourism, spill-over effects that benefit fisheries, acting as cultural heritage sites and increasing wellbeing of the general public and coastal communities (35). Quantification of these benefits is mostly lacking though (36, 37). Additionally, what is unclear is the effectiveness of static protections under climate change as habitats are altered and species move. On top of this, regulatory uncertainty can play a role in weakening protection and MPAs bio-cultural benefits, by, for example, decreasing sea-users' and the public's understanding of the conservation measures and laws in place. This may lead to non-compliance with the measures, hindering the achievement of the conservation objectives. It may also decrease users and public's perceptions of the legitimacy of the law, leading to mistrust (38).

Legitimacy is a key characteristic of democratic environmental decision-making so that a plurality of perspectives and approaches are deliberated upon for collective problem solving (39), in our case marine conservation now and into the future. Both normative legitimacy, understood as processes fostering inclusive decision-making, and perceived legitimacy in the eyes of sea users and the public are key to MPA success. Studies of legitimacy trigger also the question: 'legitimacy to whom?' This brings the discussion from the normative to the descriptive plan and accords with an exploration of legitimacy from the point of view of people's perceptions of and beliefs in the governance systems (40). Exploring marine actors' perceptions of what is a legitimate decision-making process is therefore essential. Thus, we understand legitimacy in two ways: as a democratic call to increase inclusiveness in decision-making and descriptively, as the way in which people accept or do not accept

regulatory systems in place, as this has clear value for ensuring compliance with the management measures in place.

While MPAs are intended to bring protection to marine systems, they can be perceived negatively by sea-users and the public at large as they may result in economic, social and cultural impacts for national economies (e.g., limiting renewable energy production, mining, shipping) and for regional to local food security, livelihood and cultural activities (e.g., fisheries displacement, lack of access to traditional sites) (19, 36). Tensions between costs and benefits of MPAs may generate conflicts, exacerbated by ecological and regulatory uncertainty due to environmental and political changes demanding new approaches to regulation. The ways in which these conflicts are resolved and who has a say in MPA management are key issues that require careful attention as they contribute to the legitimacy of decision-making.

Below, we start with the general considerations which relate to the type of MPAs to be established to ensure effectiveness in the face of global environmental change as well as to calls for inclusiveness to ensure normative legitimacy and recognition of multiple and potentially dynamic values in marine governance. We introduce the main changes for coastal ecosystems and their services, today and under increasing climate change risks. We then follow with the UK specific regulatory uncertainty due to the departer of the UK from the European Union. These considerations lead us to offer methodological observations regarding impactful research on MPAs governance, focusing on UK MPAs as a case study, which serves to contextualise the discussion given that each MPAs governance system is different. We close on a reflection on effectiveness of MPAs and their legitimacy.

Adaptive marine governance in the context of global environmental change

Adaptive governance is advocated as a key response to ecological, regulatory and societal uncertainty (41). In the context of marine governance, this can relate to networked and dynamic MPA design, inclusive and responsive decision-making, and institutional clarity and flexibility.

While protected areas have had some success in meeting conservation objectives, a recent IPBES IPCC report indicates that protected area designations to date have been insufficient to adequately address biodiversity loss' or something like this (42). They argue that this is due to limited protection, poor design and insufficient enforcement. The IUCN guidelines for ecological networks and corridors (43) stress how networks of interconnected protected areas are vital to ensure ecological connectivity and the survival of species (43). In contrast

to individual MPAs, networks allow migration of species at all developmental stages and, when protecting habitat formers and keystone species, have the potential to increase biodiversity and develop natural resilience.

Despite the clear link between MPA and protection, the need for protection against climate change and the importance of management plans for their success, most research about climate change and MPAs has focussed on exploration of where new MPAs and MPA networks should be designed, based on climate change trajectories (28). Despite a global increase in the area protected, the capacity of the current MPA coverage to mitigate ecological climate change impacts is arguably limited and at best uncertain as not all stressors are removed, standing stocks still impacted, and management measures for many MPAs still to be developed (44). Many MPAs by design cannot explicitly protect against climate change related disturbances (e.g. warming, changes in riverine fluxes or ocean acidification) but act via a reduction of other anthropogenic stressors, thereby supporting ecosystem health (45).

Traditionally, the focus of MPA management and stewardship incentives has been on resource-users with most direct impact on marine ecosystem health (46). Understanding MPAs as fostering potential for social-ecological system's effective adaptation to climate change impacts rather than solely as spaces for ecological conservation and protection against damaging human impacts, influences how we consider biodiversity, climate mitigation, drivers of change, and ecosystem services within decision-making and MPA governance. To ensure that networks of MPAs are accepted, understood and perceived as legitimate by actors, devising strategies that enable the participation of sea users, coastal communities and publics in decision-making is essential. Inclusive processes can account for diverse and changing value systems and foster buy-in from a broader constituency of users and stakeholders, which is essential in the context of global climate change.

Climate change scholarship has motivated a shift in who is considered to have a rightful stake in the governance of marine social-ecological systems. Resource-users directly dependent on marine SES remain important but there is also an expanding focus on the participation of the general public and how they view the legitimacy of marine SES governance, including MPA governance (47). These stakeholders include those who interact with marine spaces (e.g., walkers, swimmers and other low-impact recreational users) and/or who do not live on the coast but whose behaviours nevertheless impact these systems (e.g., microplastics, carbon emissions as well as through positive behaviours like sharing knowledge and lobbying on ocean health). This broader set of stakeholders hold a diversity of knowledges, beliefs and values regarding the ocean, which underpins their wellbeing, motivates their marine

stewardship behaviours and shapes the wider legitimacy of governance interventions in marine SES (48). Importantly, values are not always shared nor are they always positive; they can underpin conflict of what should be the focus of marine management and stewardship actions (49). Value systems are also likely to be impacted by and change in response to anthropogenic pressure and climate change as ecosystem services decline or move and governance systems change in (50).

Taking account of values is gaining traction in marine research, policy and practice. Values can describe basic human values such as conformity or benevolence (51, 52), environmental values and ethics (53, 54) and/or how ecosystem services are used and valued, often economically (55, 56).Values assessments are burgeoning as an approach to incorporating values into decision-making (e.g., Natural Capital Accounting), but with many analysts acknowledging that environmental values assessments struggle to accommodate for tangible and intangible social and cultural values (57-59). Other approaches involve routine surveying or monitoring of values as a way of bringing in more dynamic and subjective data on diverse human values and how they change (e.g., Great Barrier Reef Marine Protected Area Social and Economic Long Term Monitoring Programme (SELTMP) (60), Natural England's Monitor of Engagement with Natural Environment Survey (MENE) (61), and Scotland's People and Nature Survey (SPNS) (62). A key impetus for capturing diverse and changing values is to showcase the fundamental importance of healthy marine SES beyond ecosystems services provided to direct resource-users and, thus, to reinforce the legitimacy of management interventions, such as MPAs, whose benefits arguably accrue to societies (and future generations) as a whole. Second, capturing diverse and changing values can inform an adaptive approach to MPA design under climate and regulatory uncertainty.

Inclusive decision-making and co-production of MPA networks and associated marine plans are more often advocated for effective and legitimate marine governance decision-making, particularly in contexts of uncertainty and accelerating pressure on the ocean (63). The push for adaptive co-management becomes an essential regulatory strategy. Adaptive co-management (64) marries the narrative on collaborative resource management (65) with that of adaptive management (66), emphasizing flexibility, experimentation, and shared learning by doing between regulators, resources users, and communities. It is multi-scalar and inclusive by drawing on the capabilities and knowledge of all actors with a stake for the management of natural resources and multi-level institutional arrangements to cope with the complexity of social-ecological systems (67).

Thus, participation should extend beyond affected sea-users and coastal communities and include the public at large given that ultimately biodiversity has been identified as the common concern of humankind as expressed in the preamble of the Convention on Biological Diversity (68). Participation in environmental decision-making is indeed an essential element of international environmental law and policy. Principle 10 of the Rio Declaration 1992 stresses that environmental issues are best handled with the participation of all concerned citizens and that access to environmental information, participation in decision-making and access to justice shall be provided at national level. The UNECE Aarhus Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters is the most notable example for concretising Principle 10 in law (69). The Aarhus Convention is promoting environmental democracy and rights and should be seen as an important step in environmental law towards offering procedural safeguards to countries within the UN Economic Commission for Europe (UNECE). The Convention grants procedural rights to the public and public representatives such as environmental NGOs in relation to access to environmental information, participation in environmental decision making and access to justice (70). Such procedural safeguards ensure the legitimacy of decisions by fostering environmental democracy and also by facilitating compliance with the regulations in place, providing actors with a sense of ownership over decision-making (71). Participation is indeed both, a right in itself and an instrument to ensure compliance and effective management. It is also a fundamental pre-requisite for equitable distribution of resources. Deliberating on which adaptation strategies are acceptable and how costs and benefits of MPAs are distributed is essential given the complex and political nature of MPAs and the multiple actors that affect and are affected by them.

Having a strong legal framework for the governance of MPAs is essential as it can provide both procedural and substantive standards promoting the sustainability of a coastal social-ecological system and resolving tensions between conflictual values by promoting deliberation and co-management. Law, however, can also hinder the sustainability of a social-ecological system if too prescriptive, too front-ended, too risk adverse, and when it is too centred on the protection of selected habitats and species rather than social-ecological systems (72).

Multilateral environmental agreements, most notably the Convention on Biological Diversity (CBD) and its Conferences of the Parties (COP) decisions, are also highly relevant in promoting an inclusive view of marine conservation based on the ecosystem approach and focused on a network approach to protection. For example, CBD COP decisions on MPAs such as COP 7 Decision vii/5 (73) agrees that MPAs are a key tool in the conservation and

sustainable use of marine and coastal biodiversity (para 16) and that the goal for work under the Convention relating to marine and coastal protected areas should be the "establishment and maintenance of marine and coastal protected areas that are effectively managed, ecologically based and contribute to a global network of marine and coastal protected areas building upon national and regional systems, including a range of levels of protection, where human activities are managed, particularly through national legislation, regional programmes and policies, traditional and cultural practices and international agreements, to maintain the structure and functioning of the full range of marine and coastal ecosystems, in order to provide benefits to both present and future generations" (para 18). The so-called Malawi principles, presented at the 4th meeting of the CBD COP (74) list twelve principles of the ecosystem approach to biodiversity, stressing both substantive issues, such as the conservation of ecosystem structure and functioning (principle 5) and procedural ones, such as the involvement of all relevant sectors of society and scientific disciplines (principle 12) in the ecosystem approach (75).

Finally, soft law instruments such as the Sustainable Development Goals spelt out under Agenda 2030 complement legal obligations providing the necessary vision and push towards more sustainable and inclusive ocean governance. However, overall the enforcement of international environmental law is very difficult to achieve (76) and contracting parties are given much discretion to meet targets and obligations. Paying attention to national law is therefore essential to understand in practice the challenges for flexible and legitimate marine conservation governance. Below the example of UK MPAs is provided as it presents an interesting case in which ecological and regulatory change and uncertainty are very obvious, participatory efforts at decision-making visible and attempts at co-management also present.

3. A case study: English MPAs under climate and regulatory uncertainty

Currently, ~38% of UK waters have MPAs designations, with 47% in inshore waters and 36% in offshore waters (JNCC, 2021). The key designations are Special Areas of Conservation (SACs) and Special Protected Areas (SPAs), and Nature Conservation MPAs (ncMPAs) for Scotland and Marine Conservation Zones (MCZs) for England, Wales and Northern Ireland. Due to the environment being a devolved matter, each UK administration has developed its own legislation in relation to MPAs. For example, Scotland has the Marine (Scotland) Act 2010 whilst Norther Ireland has the Marine Act (Norther Ireland) 2013 and there are also different statutory instruments implementing retained EU law. Given that a comparative analysis of the marine conservation of all devolved administrations is beyond the scope of this opinion piece, we will focus on English law and its implementation to the

designation and management of MPAs, though referring to UK wide scientific and policy reports where necessary.

The MPA network also comprises Sites of Special Scientific Interest under the Wildlife and Countryside Act 1981 and Ramsar Sites (77). These MPAs differ in terms of designation and management measures, with some, such as SACs and SPAs, more stringent and ecocentric than others (78). Some of these sites have been devised exclusively for the marine environment (e.g. MCZs and ncMPAs), while others have been used for both the terrestrial and marine environment and are rooted in a conservation logic that is more terrestrial than marine (e.g. SSSIs as well as sSACs and SPAs). The legislation that created these sites over the last decades reflects changes and developments in scientific knowledge and economic and social drivers. Indeed, the Marine and Coastal Access Act 2009 (MCAA 2009) (79) sets out the legal framework for the MCZs governance in Part 5. It is also placing importance on the establishment of a network of MPAs, to the conservation or improvement of the UK marine environment. The MPAs network should cover the range of features present in the UK marine area and acknowledge that the designation of a feature may require the designation of more than one site (section 123 MCAA). This is an important legislative requirement and in line with what discussed in section 3 regarding the role of networks for conserving biodiversity in the context of global environmental change. Prior to the Marine and Coastal Access Act 2009, the main MPA designations were the SACs and SPAs, established under EU Habitats (80) and Birds Directives (81). Following the MCAA 2009 a (82, 83) a substantial increase in the area protected has been witnessed as this Act allowed for the establishment of new type of MPA, the MCZ (79).

Despite such increase in number of MPAs, the capacity of the existing MPA network to mitigate climate change impacts is arguably limited and at best uncertain as not all stressors are removed and standing stocks still impacted (44, 84). The most recent Marine Climate Change Impact Partnership report (85) highlights continued increasing warming, oxygen loss, acidification and sea level rise impacts on across the UK ecosystems and fisheries productivity. Extreme events increased in frequency, resulting in more extensive impacts (85), with evidence for drying dunes (86), changes in species composition in rocky intertidal habitats (87), and invasion of species (88). The extent of the impacts is often underreported due to a lack of multinational and integrated approaches to recording, forecasting and managing these impacts (89).

Designation without effective management amounts to the creation of paper parks and many MPAs are still lacking management measures (90), although in coastal areas substantial efforts have been made to manage fisheries in MPAs following a revised approach (91).

Despite protection, a recent report from the Marine Conservation Society UK, a leading marine conservation NGO, examining fishing effort in offshore Marine Protected Areas in the UK found that the majority allowed for demersal towed fishing between 2015-2018 (92). Since the report was published the UK government has proposed management measures in four large MPAs (93).

Ecological issues are not the only ones that English marine conservation law is facing. The withdrawal of the UK from the EU presents a novel and unforeseen scenario. SACs and SPAs have not disappeared as the Habitats Regulations transposing the Habitats and Birds Directives into domestic law (94) fall into the category of retained EU law under section 8 of the European Union (Withdrawal) Act 2018, thereby creating a degree of legal continuity. The Regulations have been subject to EU exit amendments (95) to bring in house reporting obligations, powers previously in the hands of the European Commission and changes to the nomenclature to erase references to the European dimension. However, much uncertainty remains. For example, it is not clear what the status of retained EU law will be in the future, when sections 112-113 of the new Environment Act 2021 (96) confer power to amend general duties and assessment provisions of the Habitats Regulations for SACs and SPAs. Secondly, the Supreme Court (97) and the Court of Appeal (98) are not bound by any retained EU case law, so they can decide to depart from it and could weaken the interpretation of marine conservation law. Thirdly, the European Commission has operated as a watchdog of environmental law, and the extent to which the new Office for Environmental Protection established under section 22of the new Environment Act 2021 will have the same weight is debatable (99).

Climate and regulatory uncertainty have the potential to elevate existing tensions and conflicts in marine space in the UK. Understanding values may provide a means to mediate and manage these conflicts but inclusive decision-making in the form of adaptive co-management, in addition to research on values, will be key.

Defra's 25 year Environment Plan emphasises the importance of understanding economic, social, historical and environmental values, how these values incentivise stewardship and sustainable behaviours, and how they can be incorporated into environmental decision-making – from policy, to licensing, to implementation and enforcement of regulation (100). While not specific to the UK's MPA network, an assessment of the UK's marine natural capital assets estimates these to contribute a value of £211 billion to UK (and global) society (59). The authors (59) call for improved granularity of marine data, and identify research on cultural values as a key gap. This is the first assessment of marine ecosystems in the UK

and with assessment techniques and data improving, there is growing interest in valuation approaches from a range of decision-making bodies.

To ensure MPAs are perceived as legitimate, especially in a context of ecological and regulatory uncertainty, it is essential that strong participatory processes as well as co-management institutional arrangements are present. Existing efforts on participation and co-management in England have produced mixed results to date, depending on whether we focus on designation or management of the MCZs. In relation to designation, MCZs, differently from SACs and SPAs, enable socio-economic considerations to be accounted for at the designation stage under section 117(7) of the Marine and Coastal Access Act 2009. To ensure proper consideration of socio-economic interests at the designation stage, four regional stakeholder groups were set up in England in 2009-2011 with representatives ranging from sea-users, to statutory bodies, to NGOs in an attempt to balance socio-economic and environmental factors. Despite efforts at inclusivity, this approach potentially did not achieve the results aimed at (101, 102). Discussions revolved more around trade-offs between different sectors, than around the search for deliberative democracy. This is problematic for ensuring normative legitimacy and, pragmatically, for rendering the process legitimate in the eyes of those involved. Secondly, the designation of sites has been slow as many sites recommended by the regional MCZs groups were not designated in the first tranche because full scientific evidence of the features to be protected was missing and a strong precautionary approach was not embraced (103).

Moving to the management of sites post-designation, some positive efforts at co-management are visible. Management institutions in England for example include the Inshore Fisheries Conservation Authorities (IFCA), which have been set up under Part 6 of the MCAA in 2009, with fisheries and conservation powers and duties. There are 10 IFCAs in England in charge of 10 different districts between the 0-6nm, where they ensure that the exploitation of sea fisheries resources is carried out in a sustainable way and that it is balanced with the need to protect the marine environment (s 153 MCAA). Members include local councillors, the Marine Management Organisation, which is the principal regulator of the marine environment (Part 1 MCAA), Natural England (a statutory conservation body) and the Environment Agency. Other members, known as Marine Management Organisation's appointees, self-nominate. This approach enables members of the public to participate in IFCA's Committees, thereby opening up the space of decision-making. IFCAs however suffer from under funding, which puts them at risk (103). Besides, IFCAs are specific to England, and in Scotland, for instance, there is no equivalent co-management institution (38)). This is important to highlight because it shows devolution can make a difference in management arrangements for MPAs. In the context of Brexit, devolved administrations may

diverge substantially in their conservation measures, without having EU law umbrella. However, species, habitats and ecosystems does not stop at administrative boundaries, especially in the context of global environmental change, requiring concerted efforts to meet complex ecological demands.

4. Conclusions and challenges ahead

Climate change and resource extraction will impact our coasts, the ecosystems and people who live in these regions. Adaptation to future climate change needs to be cognisant of the varying needs between natural and human systems. A clear acknowledgement of the interdependency of people and nature, as underpinned by the concept of SES, will be fundamental to deriving just and effective adaptations to the challenges of the next decades. The placement of protected areas which are required to maintain ecosystem integrity will determine the quality and ecological representativeness of the resulting network.

Marine SESs which address climate change, for example through climate smart marine spatial planning (104), will be fundamental to conservation, restoration and sustainable use. Knowledge of effectiveness of protection will depend on understanding baselines of ecosystem degradation and progress towards restauration and ecological recovery. Understanding the characteristics of vulnerable species can assist to minimise negative impacts and inform management intervention (105, 106). Climate services such as monitoring to deliver warning systems, risk evaluation tools and projections can support decision making if they are considering jurisdiction and decision-making practice relevant to users (107).

Governance does not only need to be adaptive, but also legitimate. To ensure legitimate decision-making processes, it is essential that democratic principles of inclusiveness and deliberation underpin the decision-making and that marine actors themselves perceive the process to be a legitimate one, as this will impact on the success and compliance rate. Accounting for the diverse and changing values of a broader set of actors to include resource-users and publics fits can reinforce the legitimacy of marine management tools that have long term societal benefits under climate and global chance.

There are many obstacles, though as demonstrated by the English case study. Administrative boundaries may challenge the achievement of an integrated response to conservation as species are on the move; co-management approaches may not give the results hoped for if trade-offs rather than deliberation are at their core and finally strong co-management institutions need to be put in place and must be well funded. Regulatory uncertainty, next to ecological one, can also hinder the development of marine conservation

law and hence studies should consider both ecological and regulatory challenges of marine governance jointly.

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